Estimates of genetic parameters among scale activity scores, growth, and fatness in pigs[1,2]

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ABSTRACT: Genetic parameters for scale activity score (AS) were estimated from generations 5, 6, and 7 of a randomly selected, composite population composed of Duroc, Large White, and 2 sources of Landrace (n = 2,186). At approximately 156 d of age, pigs were weighed (BW) and ultrasound backfat measurements (BF1, BF2, and BF3) were done. While pigs were in the scale, an AS was assigned, which ranged from 1 (calm) to 5 (highly excited), where 58.1, 28.5, 8.9, 4.0, and 0.5% were scored as 1, 2, 3, 4, and 5, respectively. Statistical model effects were year-week of measurement, sex, covariates of age for AS and BW or BW for BF1, BF2, and BF3, and an animal direct genetic effect. A 5-trait linear mixed model was used. Estimated heritabilities were 0.23, 0.54, 0.56, 0.52, and 0.48 for AS, BW, BF1, BF2, and BF3, respectively. Estimated genetic correlations between AS and BW, AS and BF1, AS and BF2, and AS and BF3 were −0.38, −0.11, −0.12, and −0.16 respectively. Results indicated AS had a heritable genetic component and was genetically correlated with performance traits. Estimated genetic correlations between AS and backfat measurements adjusted to a common BW were negative, as was the genetic correlation of AS with BW. Therefore, selection for more docile animals would be expected to result in fatter, faster growing pigs.

Key words: genetic correlation, pig, temperament

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INTRODUCTION

Domesticated livestock animals are more docile and more accustomed to human contact than their wild predecessors. Recent changes in production systems have modified husbandry practices to reduce labor and increase herd size, which has resulted in less human contact while pigs are being cared for. Fewer opportunities exist for animals to become familiar with humans, and animals may perceive human contact as more stressful (Le Neindre et al., 1996), which may result in increased potential for human as well as animal injury. In addition, excessive fear may lead to chronic stress, which is known to alter fundamental behaviors and reduce productivity (Forkman et al., 2007). Therefore, reduction of the susceptibility of pigs to being frightened should be of both economic and ethical significance for producers (Boissy et al., 2005).

Behavioral studies in swine have focused on coping in young pigs (van Erp-van der Kooij et al., 2000; Cassady, 2007) and maternal behavior in sows (Vangen et al., 2005). The resident intruder test and backtest have been used in young pigs, but they are labor and time intensive. Cattle studies have measured fear by recording flight speed and chute scores (Burrow and Corbet, 2000; Kadel et al., 2006; Nkrumah et al., 2007), and these scores have been associated with feedlot performance (Voisinet et al., 1997; Burrow and Prayaga, 2004). Although chute scores are subjective and categorical, they are quick and easy to gather, have been implemented in genetic evaluations, and have shown genetic progress in selection programs (North American Limousin Foundation, 2004).

The heritability estimates for some fear-related responses are sufficiently high to allow for selection on fearfulness. However, selection for production traits may have antagonistic behavioral implications (Grandin and Deesing, 1998; Breuer et al., 2005) and progress may be slowed when behavioral traits are added to selection programs (Boissy et al., 2005). Before fearfulness traits can be used as a potential selection parameter, a better knowledge of the relationships between fear and

[1]Mention of a trade name, a proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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production traits is required to design new breeding programs effectively. The objectives of this study were 1) to use scale activity scores (**AS**), adapted from the cattle chute scoring system, as a behavior measurement in pigs and to estimate the heritability of AS, and 2) to estimate genetic and phenotypic parameters among AS, growth, and leanness.

MATERIALS AND METHODS

All animal procedures were reviewed and approved by the US Meat Animal Research Center Animal Care and Use Committee.

Animals

A composite population was developed using Large White, Duroc, and 2 sources of Landrace. Selection of boars and gilts was random within sire-line origin. Matings were random, except that full- and half-sib matings were avoided. Twelve original sire lines were maintained, and approximately 300 females produced litters each generation. Additional details of the development of this population were reported previously (Holl et al., 2008). During generations 5 and 6, there were 4 farrowing seasons. For generation 7, there were 5 farrowing seasons. Animals used for this study were born in generations 5, 6, and 7. All gilts available at 22 wk of age as well as boars born in generations 6 and 7 were used for this study.

Data

A method of scoring pigs for temperament was developed using the 5-point chute or crush temperament score as a basis (Grandin, 1993; Voisinet et al., 1997). This test was originally developed for cattle while they were confined in a squeeze chute isolated from other animals, within close proximity to a human observer. At approximately 22 wk of age, an AS was assigned according to the behavior of the pig while the pig was restrained in the scale during the process of being weighed and having backfat measurements recorded. The 1- to 5-point AS was assigned according to the following protocol: 1) remains calm with little or no movement; 2) walks forward and backward at a slow pace; 3) continuously moves forward and backward at a rapid pace; 4) continuously moves forward and backward at a rapid pace, with high-pitched vocalization; and 5) continuously moves forward and backward, vocalizes, and attempts to escape by jumping or digging. In addition, BW, backfat behind the shoulder (**BF1**), backfat over the last rib, and backfat over the last lumbar (**BF3**) were recorded.

Statistical Analyses

Analyses were done with a 5-trait linear model. Models for all traits included nongenetic effects of sex and

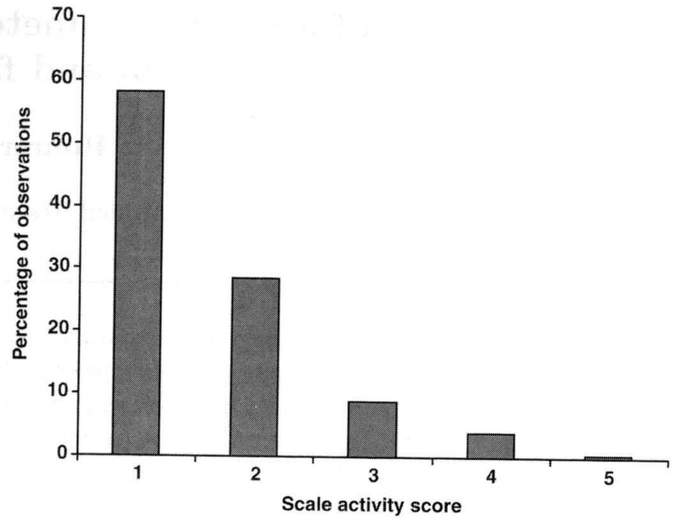

Figure 1. Distribution of scale activity scores for 2,186 animals based on a 5-point scoring system where 1 = animal is extremely calm, 2 = animal moves at a slow pace; 3 = animal continuously moves around, 4 = animal continuously moves at a rapid pace with high-pitched vocalization, and 5 = animal continuously moves with vocalization and attempts to escape.

contemporary group (defined as the combination of year and week of measurement), the direct additive genetic effect of the animal, and residual. Scorer effects on AS were included in contemporary group because there was only 1 scorer each day. The model for AS and BW also included a linear regression on age. The model for BF1, backfat over the last rib, and BF3 included linear regression on weight and a fixed effect for sex. The equation for the multiple trait linear model was

$$\mathbf{y}_{ijklm} = cg_{ij} + s_{ik} + bx_{il} + a_{im} + \mathbf{e}_{ijklm},$$

where $\mathbf{y}$ was the vector of observations; cg_{ij} was contemporary group j for trait i; s_{ik} was sex k for trait i; bx_{il} was the regression of trait i on the appropriate covariate l, as indicated above; a_{im} was the additive genetic effect for animal m for trait i; and $\mathbf{e}$ was the vector of residual effects. Genetic parameters were estimated using the REMLF90 program (Misztal, 2002).

RESULTS

The distribution of AS is shown in Figure 1. For AS, 58.1, 28.5, 8.9, 4.0, and 0.5% of pigs were in categories 1, 2, 3, 4, and 5, respectively. Phenotypic means, minima, maxima, and SD for AS, BW, and ultrasound backfat measurements are presented in Table 1. Males had greater AS than females (1.98 vs. 1.85; $P < 0.05$). Age was not a significant source of variation for AS ($P = 0.56$).

Estimates of heritability, genetic correlations, and phenotypic correlations are given in Table 2. Heritability of AS was estimated to be 0.23. In addition, estimated heritabilities for BW and backfat measurements ranged from 0.48 (BF3) to 0.56 (BF1). There was a

Table 1. Phenotypic mean, minimum, maximum, and SD for scale activity score, BW, and backfat measurements

Trait[1]	N	Mean	Minimum	Maximum	SD
AS	2,186	1.60	1.00	5.00	0.85
BW	2,186	92.61	56.96	136.12	10.56
BF1	2,116	17.51	9	37	3.64
BF2	2,186	13.41	6	26	2.75
BF3	2,116	14.33	7	26	2.84

[1]AS = scale activity score; BW = BW at 22 wk of age (kg); BF1 = backfat behind the shoulder (mm); BF2 = backfat over the last rib (mm); BF3 = backfat over the last lumbar (mm).

stronger genetic relationship between temperament and growth than between temperament and composition, as evidenced by a stronger genetic correlation between AS and BW (−0.38) compared with genetic correlations between AS and backfat traits (−0.11 to −0.16). With the exception of correlations between BW and backfat traits, genetic correlations tended to be stronger than phenotypic correlations. Adjusting backfat for BW removed part of the correlation between these traits, resulting in low genetic and phenotypic correlations. Correlations between backfat measurements (genetic and phenotypic) were near unity.

DISCUSSION

Selection programs have exploited the science of quantitative genetics to improve the efficiency of pork production systems. Improvement has been focused on traits directly affecting production, such as litter size and lean growth. Little attention has been given to behavioral traits. As a result, it has been speculated that in cattle, intense selection for growth and leanness has resulted in increased problems with very reactive cattle (Grandin and Deesing, 1998). In pigs, it has been suggested that past selection for desirable production traits has resulted in increased predisposition to tail-biting behavior (Breuer et al., 2005).

Swine production systems also have modified husbandry practices because of a reduction in labor and increases in herd size, which has resulted in a general reduction in human contact while pigs are being cared for. This reduces opportunities for animals to become familiar with humans and increases opportunities for pigs to perceive handling as stressful (Le Neindre et al., 1996). Excessive fear may lead to chronic stress, which is known to alter fundamental behaviors (social, sexual, and parental relationships) and reduce productivity (Forkman et al., 2007). Therefore, reducing the susceptibility of pigs to being frightened (i.e., fearfulness) should improve their ability to adapt and is likely to be of economic and ethical significance for producers.

Most evidence that fear reactions are heritable has been shown in laboratory species (Ramos and Mormede, 1997). Similarly, apart from tests implicating exposure to humans, most tests used with farm animals were originally designed for laboratory animals. These tests were generally used for applied ethology in laboratory species, and their biological significance for farm animals is unknown. This feature may lead to an inaccurate estimation of fear in farm animals, thus providing an explanation for the lack of a link between studies of laboratory and farm animal species (Forkman et al., 2007).

Behavior traits are often difficult to observe and record on a large scale (Grandinson, 2005). In young pigs, the resident intruder test (30 to 60 d of age) and the backtest (up to 17 d of age) have been used to measure coping behavior, but they are labor intensive (van Erp-van der Kooij et al., 2000; Cassady, 2007). In addition, research has indicated that the resident intruder test and backtest are independent measures of coping behavior (D'Eath, 2002; Cassady, 2007). Subjective on-farm sow surveys have also been used (Vangen et al., 2005), in which maternal behavior was scored from 1 to 7 for 11 sow traits.

Cattle studies have measured fear by measuring flight speed and chute (crush) scores (Burrow and Cor-

Table 2. Model 1 estimates of genetic correlations (above diagonal), heritabilities (on diagonal), and phenotypic correlations (below diagonal)[1]

Trait	AS	BW	BF1	BF2	BF3
AS	0.23	−0.38	−0.11	−0.12	−0.16
BW	−0.06	0.54	−0.01	−0.01	0.10
BF1	0.03	0.07	0.56	0.89	0.87
BF2	0.02	0.06	0.85	0.52	0.98
BF3	0.00	0.13	0.80	0.88	0.48

[1]AS = scale activity score; BW = BW at 22 wk of age (kg); BF1 = backfat behind the shoulder (mm); BF2 = backfat over the last rib (mm); BF3 = backfat over the last lumbar (mm).

bet, 2000; Kadel et al., 2006; Nkrumah et al., 2007). These data are relatively quick and easy to gather. In addition, the North American Limousin Foundation (2004) has implemented a genetic evaluation for these measures and has reported genetic changes in temperament. However, adaptation of these measurements to pigs has not been reported.

Research has indicated a genetic component to fearfulness in pigs (van Erp-van der Kooij et al., 2000; Cassady, 2007). In the present study, AS was moderately heritable, with an estimate of 0.23, which is within the range of 0.15 to 0.30 for estimated cattle chute score heritabilities (Burrow and Corbet, 2000; Kadel et al., 2006). In addition, the estimated heritability from this study tended to be larger than estimated sow behavioral heritabilities (Vangen et al., 2005). This may be expected because fearfulness has been shown to decrease with age in cattle, causing heritabilities to decline with age (Burrow et al., 1988).

The stress behavior response has varied associations with production traits. Greater backtest scores (i.e., a greater number of escape attempts) were associated with faster growth (van Erp-van der Kooij et al., 2003). No relationship was identified by Cassady (2007) or van Erp-van der Kooij et al. (2000). In contrast to these findings, the estimated genetic correlations indicated greater AS (more active) were associated with slower growth. Studies in cattle support the estimated effects, in which greater chute scores were associated with slower growth (Burrow and Dillon, 1997; Voisinet et al., 1997). In addition, greater chute activity was related to decreased feed intake and consequently greater feed conversion rates (Nkrumah et al., 2007). In pigs, greater backtest scores were associated with decreased fatness and increased lean meat percentage (van Erp-van der Kooij et al., 2000, 2003). The genetic correlations estimated from the present study would be in agreement with the direction of these findings. However, the magnitude of the estimated effects was small and could explain the contrast of a report by Cassady (2007), in which no association was found between fatness and backtest score.

Gianola (1979) previously determined that estimated heritabilities for categorical traits with an underlying quantitative genetic component from a threshold model would be greater than estimates obtained from a linear model because the threshold model accounts for asymmetry of the categorical trait. We also observed a larger estimated heritability for AS (0.30) when these data were analyzed with a threshold model (THRGIBBS2F90 and POSTGIBBSF90; Misztal et al., 2002), but all other genetic parameters were similar (data not shown).

In conclusion, AS were moderately heritable in pigs. Calmer AS were desirably correlated with growth but antagonistically correlated with fatness. Development of a selection program to reduce AS while maintaining leanness should result in faster growing, more docile animals in subsequent generations.

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